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Assessment of Water Presence in River Channels Using Airborne LiDAR Data

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Abstract:

Watercourses play a key role in shaping the natural framework of a region, influencing the landscape, climatic conditions, and the environment of both humans and ecosystems. Rivers are dynamic systems whose morphology evolves under the influence of hydrological, geomorphological, and anthropogenic factors. To effectively manage land use, support spatial planning, and protect natural resources, a comprehensive understanding of these complex systems is essential.

In modern conditions, such understanding depends on the availability of high-quality spatial data describing the location, elevation, and current state of natural features. However, mapping river networks remains a challenging task. River systems often extend across large and difficult-to-access areas, making traditional surveying methods inefficient. Furthermore, their dynamic nature leads to continuous changes in channel geometry and flow conditions. A key component of accurate river mapping is the detection of water presence within channels, which enables the distinction between active, water-filled channels and dry or intermittent ones. Therefore, there is a strong need to regularly update river network datasets to reflect their current state and support effective environmental management.

Airborne LiDAR has emerged as a powerful technology for high-resolution mapping of natural environments, providing detailed three-dimensional point clouds of terrain and surface features. These data facilitate the classification of vegetation, built structures, and geomorphological elements based on their geometric and radiometric properties. Airborne LiDAR systems typically operate in the near-infrared (NIR) spectrum (around 1064 nm), where water strongly absorbs laser energy. As a result, water surfaces often produce weak or no returns, or cause specular reflections away from the sensor, leading to distinctly low intensity values (Höfle et al., 2007). These characteristics can be effectively exploited to distinguish water bodies from surrounding terrain.

Building on this principle, several studies have demonstrated the potential of integrating LiDAR intensity and elevation data for hydrological feature extraction. Notably, Hooshyar et al. (2015) introduced a methodology for wet channel network extraction that combines LiDAR-derived elevation models with intensity information to enhance the detection of water-filled channels. Their work highlights the importance of jointly analyzing geometric and radiometric attributes to improve the delineation of active river networks.

In this study, we extend this concept by integrating airborne LiDAR data with a set of preprocessing steps and filtering techniques applied at the raster level. To address the occlusion of riverbanks by dense vegetation — particularly in challenging terrain — we exploit native LiDAR properties such as laser pulse penetration through the vegetation canopy and multiple return classification, enabling the recovery of ground-level information beneath vegetated areas. Specifically, spatial, radiometric, and morphological filters are employed to enhance data quality, reduce noise, and emphasize features associated with water presence — including runoff simulation using the D-infinity (DINF) method (Tarboton, 1997), valley delineation via the Topographic Position Index (TPI) (Weiss, 2001), masking of dense vegetation while preserving intensity values near riverbanks, edge enhancement through the Perona-Malik filter (Perona and Malik, 1990), Canny edge extraction (Canny, 1986), and terrain roughness analysis. These preprocessing steps aim to improve the separability between water surfaces, bare soil, and vegetation, thereby generating more robust input datasets.

The derived features are subsequently used as input variables for machine learning algorithms designed for the automated detection and delineation of river channels. By combining information on water presence with terrain characteristics, the proposed workflow aims to improve the extraction of river networks as polygonal features.

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Ultimately, this approach contributes to more accurate and up-to-date mapping of river systems, supporting geospatial database maintenance, environmental monitoring, and sustainable land management.

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